Journal of Bone Oncology xx (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Journal of Bone Oncology

journal homepage: www.elsevier.com/locate/jbo

Review Article

Use of percutaneous core needle biopsy for diagnosing acral bone tumors

Zhichao Tong[a,*], Mingyu Zhang[b], Bo Chen[a], Yujie Zhu[a], Jianfeng Wei[a], Xiaoju Li[c]

[a] *Department of Bone Disease and Bone Tumor, Xi'an Honghui Hospital, Medical College of Xi'an Jiaotong University, Xi'an 710054, China*
[b] *Department of Sports Medicine, Xi'an Honghui Hospital, Medical College of Xi'an Jiaotong University, Xi'an 710054, China*
[c] *Department of Pathology, Xi'an Honghui Hospital, Medical College of Xi'an Jiaotong University, Xi'an 710054, China*

ARTICLE INFO

Keywords:
Percutaneous core needle biopsy
Imaging
Bone tumor

ABSTRACT

This study aims to evaluate the diagnostic value of percutaneous core needle biopsy (PCNB) in diagnosing acral bone tumors. The clinical PCNB data of 341 patients with bone tumors were retrospectively analyzed. The diagnostic accuracy was calculated according to the lesion components (sclerotic, parenchymatous, or cystic), benign or malignant character, and whether a soft tissue mass was present. The chi-square test was performed to assess diagnostic accuracy. The accuracy rate for sclerotic and substantive lesions was high (87.5% and 90.1%, respectively), while that for cystic lesions was the lowest. The accuracy difference in diagnosing benign and malignant lesions was significant ($P < 0.001$). The existence of an extraskeletal soft tissue mass significantly affected the diagnostic accuracy (P=0.007). PCNB is a safe, accurate, rapid, and effective screening method in diagnosing bone tumors; however, the diagnostic accuracy for cystic lesions was poorest. The lesions without a diagnostic biopsy result were most likely to be benign, and the existence of an extraskeletal soft tissue mass significantly affected diagnostic accuracy; therefore, the correct diagnosis of skeletal system lesions still relies on the coordinated efforts of clinics, pathology, and imaging.

1. Introduction

Because the clinical manifestations and treatment methods of patients with bone and soft tissue tumors are diverse, determination of the best treatment options requires a complete assessment before starting comprehensive treatment. Therefore, obtaining tissue samples for histopathological diagnosis is an important step prior to the treatment of bone and soft tissue tumors. Biopsy plays a critical role, with the purpose of obtaining tissues for diagnosis in order to reduce complications, prevent potential tumor spread, and avoid interfering with future treatments [1].

Currently, open or closed biopsy (needle-aspiration or core needle biopsy) is used to obtain tissue samples. Inappropriate biopsy fails to provide a tissue diagnosis, and affects limb salvage and survival rates [2]. Although open biopsy is considered to be the diagnostic reference standard, with accuracy as high as 98%, it also has an up to 16% risk of complications such as bleeding, infection, nerve damage, and tumor spread [3,4]. Because many malignant tumors required amputation in the past, biopsy had little significance for treatment. With the development of limb salvage methods, changes in biopsy techniques, with reduced complications, especially tissue contamination, have become very important. Percutaneous and open biopsy had similar diagnostic accuracy [5], but the complication rate of percutaneous biopsy was as low as 0–10% [1]. Since the rate of false negatives with needle aspiration biopsy was high and the diagnostic accuracy was low [6], it could not be used to assess tissue structures, but could only provide cytological material, and was not the preferred method for the diagnosis of bone tumors [1]. Therefore, instead of open biopsy, percutaneous core needle biopsy (PCNB) was developed, and has become the most simple and economical method for the diagnosis of bone and soft tissue tumors, with high diagnostic accuracy and low complication rates [1,7,8].

This study retrospectively analyzed the clinical PCNB data of 341 patients with bone tumors seen in our department from March 2007 to March 2015; the positive diagnostic rate and accuracy of PCNB was determined according to lesion components (sclerotic, parenchymatous, or cystic), benign or malignant character, and whether a soft tissue mass was present, in order to analyze and evaluate diagnostic results, and to assess diagnostic value and safety.

2. Materials and methods

2.1. General information

Between March 2007 and March 2015, a total of 341 patients underwent PCNB in our department for pathological diagnosis; there

* Corresponding author.
E-mail address: zhichaotongdoc@163.com (Z. Tong).

http://dx.doi.org/10.1016/j.jbo.2016.10.001
Received 1 September 2016; Received in revised form 12 October 2016; Accepted 12 October 2016
Available online xxxx

Please cite this article as: Tong, Z., Journal of Bone Oncology (2016), http://dx.doi.org/10.1016/j.jbo.2016.10.001

were 179 men and 162 women, with an average age of 46 years 3–84 years). The lesions were located in the femur (126 cases), tibia (80), humerus (47), radius (29), pelvis (20), ulna (17), and hand-foot-scapula (22). This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Xi'an Jiaotong University. Written informed consent was obtained from all participants.

2.2. Biopsy procedures

The lesion imaging data, including radiography (Type C arm X-ray machine from SHIMADZU WHA–200, Japan), computed tomography (CT) (PHILIPS brilliance-16, Netherland), and magnetic resonance imaging (MRI) (Siemens 3.0T Magnetom verio, Germany), were carefully studied before the biopsy; then, a direct and appropriate puncture approach was selected, which would avoid damaging the mesooecium, blood vessels, nerves, and vital organs. A total of 255 patients were operated on under local anesthesia, 86 received epidural anesthesia, and 42 were operated on under CT guidance, and 74 were operated on under radiography guidance; based on visual inspection of the samples, the biopsy specimens were expected to contain tumor tissue, necrotic tumor, necrotic tissue, or regenerated fiber vessels. Usually, three puncture attempts were able to obtain satisfactory samples; specimens 1–3 cm long were adequate, but cystic samples were difficult to obtain by puncture and were sampled repeatedly up to 5–6 times. All lesions, including coagulated blood, were fixed in 10% formaldehyde solution for examination.

2.3. Evaluation of PCNB results

The lesions were divided according to imaging features into sclerotic, parenchymatous, or cystic lesions; sclerotic lesions referred to those with more than 50% intralesional density equal to or higher than that of surrounding normal bone tissue. Parenchymatous lesions were those with more than 50% intralesional tumor component as parenchymatous soft tissue; cystic lesions referred to those with more than 50% intralesional component displaying liquid, blood, or air-fluid levels on CT or MRI. Soft tissue masses were classified according to their imaging features for evaluation. The biopsy results were assessed and compared with the gross specimen pathological results and clinical course of benign lesions, in order to calculate the positive diagnostic and accuracy rates of PCNB; complications of PCNB were also recorded.

2.4. Statistical methods

SPSS 17 was used for the chi-square trend test, with $P < 0.05$ considered as statistically significant.

Table 1
Final diagnostic results by PCNB (n=341).

Benign (n=178)	n	Malignant (n=165)	n
Bone giant cell tumor	55	Metastatic tumor	58
Chondroblastoma	16	Osteosarcoma	35
Tuberculosis	7	Myeloma	15
Fibrous dysplasia	13	Lymphoma	8
Osteomyelitis	6	Chondrosarcoma	16
Enchondroma	11	Pleomorphic sarcoma	13
Aneurysmal bone cyst	15	Alveolar sarcoma	3
Eosinophilic granuloma	7	Synovial sarcoma	4
Non-ossifying fibroma	4	Ewing's sarcoma	6
Hemangioma	4	Liposarcoma	2
Simple bone cyst	11	Fibrosarcoma	1
Desmoid tumor	5	Leiomyosarcoma	1
Bone infarction	4	Paraganglioma	1
Benign fibrous histiocytoma	6		
Hematoma	3		
Myositis ossificans	4		
Ossifying fibroma	1		
Post-GCT necrosis	1		
Cartilage fibroma	3		
Lipoma	1		

3. Results

The 341 patients underwent 354 punctures; 11 patients were punctured twice in the same lesion, and 13 were punctured at two different lesions. The most common benign tumors were bone giant cell tumor (n=55), cartilage blastoma (n=16), and aneurysmal bone cyst (n=15); the most common malignant tumors were metastatic tumor (n=58), osteosarcoma (n=35), chondrosarcoma (n=15), and myeloma (n=15). The final diagnostic results are shown in Table 1.

3.1. Positive diagnostic rate and accuracy rate of PCNB

A total 312 cases exhibited yielded PCNB results, and 29 cases had unclear or no diagnosis (among whom 9 then underwent open biopsy); the overall positive diagnostic rate was 91.5% (312/341), with accuracy of 85.6% (292/314). The statistical results are shown in Tables 2–4. There was no significant difference in the accuracy rates for sclerotic (87.5%) and parenchymatous lesions (90.1%) (P=0.481), while the accuracy rate of cystic lesions was the poorest (55%) ($P < 0.001$). The positive rates for sclerotic (90.3%) and parenchymatous lesions (95.6%) showed no statistical difference, while the differences in positive rates of sclerotic/parenchymatous and cystic lesions were statistically significant ($P < 0.05$). The accuracy rates for malignant (93.3%) and benign lesions (78.7%) showed a significant difference ($P < 0.001$), and the positive diagnostic rates for malignant (97.5%) and benign lesions (86%) were significantly different ($P < 0.001$). The

Table 2
Positive rate and accuracy rate of PCNB towards sclerotic, parenchymatous, or cystic lesions.

Classification	Total	PCNB diagnosis			Final diagnosis	
		Positive rate	Unclear or no diagnosis	Positive rat%	Correct diagnosis	Accuracy rat%
Sclerotic, lesions	72	65	7	90.3	63	87.5
Parenchymatous, lesions	229	219	10	95.6	207	90.1
Cystic lesions	40	28	12	70	22	55
Total	341	312	29	91.5	292	85.6

Note: Positive diagnostic rate: sclerotic and parenchymatous lesions: X^2=2.948, P=0.086; sclerotic and cystic lesions: X^2=7.506, P=0.006; parenchymatous and cystic lesions: X^2=29.794, $P < 0.001$; accuracy rate: sclerotic and parenchymatous lesions: X^2=0.496, P=0.481; sclerotic and cystic lesions: X^2=14.845, $P < 0.001$; parenchymatous and cystic lesions: X^2=33.697, $P < 0.001$.

Table 3
Positive rate and accuracy rate of PCNB towards benign and malignant tumors.

Classification	Total	PCNB diagnosis			Final diagnosis	
		Positive rate	Unclear or no diagnosis	Positive rat%	Correct diagnosis	Accuracy rat%
Benign lesions	178	153	25	86.0	140	78.7
Malignant lesions	163	159	4	97.5	152	93.3
Sum	341	312	29	91.5	292	85.6

Note: Benign and malignant tumors: positive diagnostic rate: X^2=14.691, $P < 0.001$; accuracy rate: X^2=14.739, $P < 0.001$.

Table 4
Positive rate and accuracy rate of PCNB towards tumors with or without extraskeletal soft tissue mass.

Classification	Total	PCNB diagnosis			Final diagnosis	
		Positive rate	Unclear or no diagnosis	Positive rat%	Correct diagnosis	Accuracy rat%
With	63	63	0	100	59	93.7
Without	278	249	29	89.6	233	83.8
Sum	341	312	29	91.5	292	85.6

Note: Tumors with or without extraskeletal soft tissue mass: positive diagnostic rate: X^2=7.183, P=0.007; accuracy rate: X^2=4.232, P=0.040.

diagnostic accuracies of lesions with or without an extraskeletal soft tissue mass were 93.7% and 83.8% (P=0.007), respectively, and the positive diagnostic rates were 100% and 89.6%, respectively (P=0.040).

3.2. Open biopsy

Among the 29 cases without a clear PCNB diagnosis, 9 underwent open biopsy, and 4 were confirmed to be malignant tumors: telangiectatic osteosarcoma, low-grade chondrosarcoma, osteosarcoma, and osteoblastic osteosarcoma; 25 cases were benign, with the main lesions being Langerhans cell hyperplasia, simple bone cyst, aneurysmal bone cyst, fracture healing, degenerative changes, and osteomyelitis/inflammation.

3.3. Complications

Among all patients, only 1 experienced a complication: this patient had a proximal humerus chondroblastoma, and had a hematoma after PCNB; the main symptoms and pain were controlled with a pressure dressing. The complication rate for PCNB was 0.29% (1/341).

4. Discussion

Open biopsy has been considered the gold standard of diagnosis, but compared with needle-aspiration biopsy, it has a high risk of local contamination, mainly because the incision must be large enough for hemostasis. For this reason, only cases of unsuccessful percutaneous biopsy, lack of clear diagnosis by percutaneous biopsy, or results of percutaneous biopsy inconsistent with clinical or imaging manifestations would undergo open biopsy [2]. The rate of wound complications of open biopsy leading to amputation was as high as 4.5% [9]. Although PCNB also had a risk of iatrogenic spread or implantation of tumor cells along the needle track [10,11], the incidence was very low, and the possibility could be ignored [12]. Most researchers did not report the recurrence of osteosarcoma within the biopsy channel [12–14]. The complications of PCNB are very low. The procedures strictly abide by the principles of cancer surgery and anatomical relationships of the mesooecium, and avoid the impact of biopsy complications on future surgeries. Anderson et al. [15] discussed the relationship between percutaneous biopsy and the mesooecium, and suggested that the relationship between the mesooecium and the surgical approach should also be recognized in the initial puncture; in biopsies of sarcoma, 25% of patients might be punctured improperly, requiring a change in the surgical approach in 10%, with 3% requiring amputation [16,17]. In this study, the overall complication rate was very low (0.29%, 1/341); 1 patient had bleeding without nerve damage. However, this operation must still avoid blood vessels and nerve bundles to avoid mesooecium contamination.

The components of intratumoral lesions are an important factor affecting the success rate of percutaneous biopsy; in the past, due to difficulties in sampling sclerotic lesions, the success rate was low. The use of modern needles made the puncture of sclerotic lesions less difficult [14]. The modern core needle is a cannula needle; the outer cannula is a ring driller that can directly break through and sample sclerotic and tumorous bone. Thus, the tissue structures could be protected, enabling not only histological diagnosis and tumor grading, but also immunohistochemistry and molecular analysis, without affecting histological evaluation. In this study, 72 cases were sclerotic lesions, among which the malignant lesions mainly included chondrosarcoma, osteosarcoma, and lymphoma; the benign lesions mainly included chondroblastoma and fibrous dysplasia, while the infectious lesions mainly included osteomyelitis and bone tuberculosis. The cortical bone of the sclerotic lesions could be easily penetrated, with strong surgical hand-feel, and a larger volume of tumor samples could be easily obtained; the diagnostic accuracy rate of sclerotic lesions showed no significant difference from that of parenchymatous lesions.

Percutaneous biopsy for parenchymatous non-sclerotic lesions was able to obtain sufficient specimen to confirm the diagnosis. Uncommon tumors or uncommon pathological features would make the diagnosis of bone tumors more difficult, and even a single lesion with mixed cystic characteristics or sclerotic regions of a bone tumor would make the diagnosis difficult; therefore, percutaneous biopsy must be performed in different areas to avoid misdiagnosis. In this study, 229 cases were parenchymatous, the main part of the tumor was neither matrix nor cystic, and the specimens were relatively easily to obtain. Sampling of a 1–3 cm-long noncystic lesions was required in order to obtain various features of the tumors, enabling improved diagnostic and accuracy rates for percutaneous biopsy. For deep tumors, CT/radiography guidance was simple and safe, and could improve the diagnostic accuracy of percutaneous biopsy [18,19].

Cystic lesions contain liquid, blood, and necrotic tissue, making it difficult to obtain adequate pathological specimens; therefore, the diagnosis might be difficult. Cystic lesions with air-fluid levels on CT and MRI are a challenge for the selection of open biopsy or PCNB [20]; the solid tissues inside the CT- and MRI-enhanced scanning area include the diagnostic tissues, and the liquid regions include the nondiagnostic tissues, making it difficult for PCNB to obtain adequate core solid tissues for diagnosis. The blood/fluid drawn from lesions usually did not yield sufficient tumor cells for diagnosis. Therefore, obtaining simple blood or liquid would be considered invalid for diagnosis, and the accuracy rate would be the lowest (55%) ($P < 0.001$).

Sixty-three lesions were surrounded by extraskeletal soft tissue masses. Because the extraskeletal soft tissue mass of malignant bone tumors also had the characteristics of the tumors [1], the presence or absence of an extraskeletal soft tissue mass would significantly affect the accuracy and positive rates of the biopsy; the diagnostic accuracy of benign and cystic tumors lacking extraskeletal components was worse. This study also found that the diagnostic accuracy for metastatic tumors was as high as 100%, consistent with other reports [21–23]; the reason for this high rate of accuracy might be due to the homogeneous characteristics of metastatic tumors, which made it easier for PCNB to access tumor cells for the diagnosis [21,24].

In this study, the positive diagnostic rate for malignant lesions was 97.5%, while that of benign lesions was low (86%) ($P < 0.001$). The 29 cases with no clear PCNB diagnosis underwent open biopsy or close clinical follow-up; among these, 25 cases were benign, and mainly comprised Langerhans cell hyperplasia, simple bone cyst, aneurysmal bone cyst, fracture healing, degenerative changes, and osteomyelitis/inflammation. Four cases were confirmed to be malignant tumors, i.e., telangiectatic osteosarcoma, low-grade cartilage sarcoma, osteosarcoma, and osteoblastic osteosarcoma. We further investigated cases without a clear diagnosis, and found that a reason for these diagnostic results was that benign lesions did not yield a clear diagnosis through puncture biopsy. The case of a malignant tumor without a clear PCNB diagnosis was rare, mainly because the sampled biopsy specimen was not typical, or not representative. Although some cases could be benign or malignant, the tissue classification could not be clarified because the specimens were small. Our findings suggested that the results with unclear or no PCNB diagnosis would be more likely to be benign lesions, and this result could guide our clinical process [25].

With the evolution of biopsy techniques, as well as needle materials, specimens obtained by PCNB are sufficient to be widely accepted by bone oncologists. Percutaneous biopsy is very effective and accurate, with low cost, little trauma, and fewer complications; the needle track is easily resected in extensive or radical surgery [9,17,26–28]. However, we must recognize that there could a certain misdiagnosis rate. If there are significant differences among clinical, radiological, and PCNB findings, open biopsy must be performed to confirm the diagnosis; it should also be recognized that not all misdiagnoses from PCNB might be corrected by open biopsy.

An incorrect or absent PCNB diagnosis could easily lead to incorrect treatment or catastrophic therapeutic consequences, improvement of the accuracy of PCNB, particularly for malignant tumors, still requires further study. Currently, computer navigation-guided puncture could further improve diagnostic accuracy of PCNB for malignant tumors. As for suspected malignant lesions (< 1 cm), the diagnostic accuracy rate of PCNB could be low, and excision biopsy or computer navigation-guided radiofrequency ablation should be performed.

The purpose of biopsy is to obtain diagnostic tissues; meanwhile, it should have minimum complications, limit the potential spread of tumors, and avoid interfering with subsequent treatments [1,6]. PCNB should be performed prior to open biopsy because of its low contamination risk and cost. In addition, image-guided biopsy could improve diagnostic accuracy and reduce the incidence of complications. However, if percutaneous biopsy yields no diagnosis, a small incision is required for open biopsy. Correct diagnosis requires a combination of clinical, radiological, and pathological results, and the information from these three modalities needs to be comprehensively considered in order to make the correct diagnosis.

Conflicts of interest

All of the authors declare that they have no conflicts of interest regarding this paper.

References

[1] F. Traina, C. Errani, A. Toscano, C. Pungetti, D. Fabbri, A. Mazzotti, D. Donati, C. Faldini, Current concepts in the biopsy of musculoskeletal tumors, J. Bone Jt. Surg. Am. 97 (2015) e7.

[2] J. Bickels, J.S. Jelinek, B.M. Shmookler, R.S. Neff, M.M. Malawer, Biopsy of musculoskeletal tumors. Current concepts, Clin. Orthop. Relat. Res. 368 (1999) 212–219.

[3] A. Datir, P. Pechon, A. Saifuddin, Imaging-guided percutaneous biopsy of pathologic fractures: a retrospective analysis of 129 cases, AJR Am. J. Roentgenol. 193 (2009) 504–508.

[4] G.J. den Heeten, J. Oldhoff, J.W. Oosterhuis, H. Schraffordt Koops, Biopsy of bone tumours, J. Surg. Oncol. 28 (1985) 247–251.

[5] F. Pohlig, C. Kirchhoff, U. Lenze, J. Schauwecker, R. Burgkart, H. Rechl, R. von Eisenhart-Rothe, Percutaneous core needle biopsy versus open biopsy in diagnostics of bone and soft tissue sarcoma: a retrospective study, Eur. J. Med. Res. 17 (2012) 29.

[6] S. Kasraeian, D.C. Allison, E.R. Ahlmann, A.N. Fedenko, L.R. Menendez, A comparison of fie-needle aspiration, core biopsy, and surgical biopsy in the diagnosis of extremity soft tissue masses, Clin. Orthop. Relat. Res. 468 (2010) 2992–3002.

[7] P. Srisawat, P. Veeraphun, T. Punyaratabandhu, S. Chareonvareekul, T. Songpattanasilpa, P. Sritanabutr, S. Pipithkul, Comparative study of diagnostic accuracy between office-based closed needle biopsy and open incisional biopsy in patients with musculoskeletal sarcomas, J. Med. Assoc. Thai. 97 (2014) S30–S38.

[8] E. Rimondi, G. Rossi, T. Bartalena, R. Ciminari, M. Alberghini, P. Ruggieri, C. Errani, A. Angelini, T. Calabrò, C.N. Abati, A. Balladelli, C. Tranfaglia, A.F. Mavrogenis, D. Vanel, M. Mercuri, Percutaneous CT-guided biopsy of the musculoskeletal system: results of 2027 cases, Eur. J. Radiol. 77 (2011) 34–42.

[9] H.J. Mankin, T.A. Lange, S.S. Spanier, The hazards of biopsy in patients with malignant primary bone and soft-tissue tumors, J. Bone Jt. Surg. Am. 64 (1982) 1121–1127.

[10] A.J. Huang, S.V. Kattapuram, Musculoskeletal neoplasms: biopsy and intervention, Radiol. Clin. North Am. 49 (2011) 1287–1305.

[11] C.H. Lee, J.W. Lee, S.J. Hyun, K.J. Kim, T.A. Jahng, H.J. Kim, Needle-tract seeding after percutaneous vertebroplasty: a case report, Spine (Philos. Pa 1976) 39 (2014) 752–756.

[12] S. Saghieh, K.Z. Masrouha, K.M. Musallam, R. Mahfouz, M. Abboud, N.J. Khoury, R. Haidar, The risk of local recurrence along the core-needle biopsy tract in patients with bone sarcomas, Iowa Orthop. J. 30 (2010) 80–83.

[13] H.S. Schwartz, D.M. Spengler, Needle tract recurrences after closed biopsy for sarcoma: three cases and review of the literature, Ann. Surg. Oncol. 4 (1997) 228–236.

[14] J.S. Jelinek, M.D. Murphey, J.A. Welker, R.M. Henshaw, M.J. Kransdorf, B.M. Shmookler, M.M. Malawer, Diagnosis of primary bone tumors with image guided ercutaneous biopsy: experience with 110 tumors, Radiology 223 (2002) 731–737.

[15] M.W. Anderson, H.T. Temple, R.G. Dussault, P.A. Kaplan, Compartmental anatomy: relevance to staging and biopsy of musculoskeletal tumors, AJR Am. J. Roentgenol. 173 (1999) 1663–1671.

[16] A.G. Huvos, The importance of the open surgical biopsy in the diagnosis and treatment of bone and soft tissue tumors, Hematol. Oncol. Clin. North Am. 9 (1995) 541–544.

[17] H.J. Mankin, C.J. Mankin, M.A. Simon, The hazards of biopsy, revisited, J. Bone Jt. Surg. Am. 78 (1996) 656–663.

[18] M.R. Nouh, H.M. Abu Shady, Initial CT-guided needle biopsy of extremity skeletal lesions: diagnostic performance and experience of a tertiary musculoskeletal center, Eur. J. Radiol. 83 (2014) 360–365.

[19] S. Steil, S. Zerwas, G. Moos, F. Bittinger, T. Hansen, U. Mergenthaler, R. Weide, CT-guided percutaneous core needle biopsy in oncology outpatients: sensitivity, specificity, complications, Onkologie 32 (2009) 254–258.

[20] A.G. Ayala, J.Y. Ro, C.V. Fanning, J.P. Flores, A.W. Yasko, Core needle biopsy and fine-needle aspiration in the diagnosis of bone and soft-tissue lesions, Hematol. Oncol. Clin. North Am. 9 (1995) 633–651.

[21] P. Kiatisevi, V. Thanakit, B. Sukunthanak, M. Boonthatip, S. Bumrungchart, K. Witoonchart, Computed tomography-guided core needle biopsy versus incisional biopsy in diagnosing musculoskeletal lesions, J. Orthop. Surg. (Hong Kong) 21 (2013) 204–208.

[22] S. Tsukushi, Y. Nishida, Y. Yamada, M. Yoshida, N. Ishiguro, CT-guided needle biopsy for musculoskeletal lesions, Arch. Orthop. Trauma Surg. 130 (2010) 699–703.

[23] E.F. McCarthy, CT-guided needle biopsies of bone and soft tissue tumors: a pathologist's perspective, Skelet. Radiol. 36 (2007) 181–182.

[24] K.S. Sung, S.W. Seo, M.S. Shon, The diagnostic value of needle biopsy for musculoskeletal lesions, Int. Orthop. 33 (2009) 1701–1706.
[25] M.M. Didolkar, M.E. Anderson, M.G. Hochman, J.G. Rissmiller, J.D. Goldsmith, M.G. Gebhardt, J.S. Wu, Image guided core needle biopsy of musculoskeletal lesions: are nondiagnostic results clinically useful?, Clin. Orthop. Relat. Res. 471 (2015) 3601–3609.
[26] J.W. Serpell, S.H. Fish, C. Fisher, J.M. Thomas, The diagnosis of soft tissue tumours, Ann. R. Coll. Surg. Engl. 74 (1992) 277–280.
[27] M.A. Simon, Current concepts review: biopsy of musculoskeletal tumors, J. Bone Jt. Surg. Am. 64 (1982) 1253–1257.
[28] S.J. UyBico, K. Motamedi, M.C. Omura, S.D. Nelson, F.C. Eilber, J. Eckardt, L.L. Seeger, Relevance of compartmental anatomic guidelines for biopsy of musculoskeletal tumors: retrospective review of 363 biopsies over a 6-year period, J. Vasc. Interv. Radiol. 23 (2012) 511–518.